UNITED STATES AIR FORCE MATERIALS TECHNOLOGY HIGHLIGHTS

Air Force Research Laboratory

Materials & Manufacturing Directorate

Wright-Patterson Air Force Base • Dayton, Ohio Summer 2006

ML Evaluates Life-Saving Body Cooling Technology for Firefighters

The Air Force Research Laboratory's Materials and Manufacturing Directorate (AFRL/ML) has begun testing the Vapor Relief ™ System, a new off-the-shelf technology that is leading the way in providing firefighters with the means to stay cool even when the conditions are hot.

Firefighters face innumerable challenges, from fighting the fire itself, to enduring intense heat and stress, especially during hot/humid weather conditions. For them, heat stress is a leading cause of on-scene debilitating injuries and, in some cases, death from heat strokes. The development of a technology that would provide a method of keeping firefighters cool could prevent injuries and possibly save the lives of Air Force firefighters.

During the 2004 International Association of Fire Chiefs and Department of Defense Fire Conference, a demonstration was conducted of the Vapor Relief ™ System (VRS), which provides a new method for firefighters to stay cool in extreme heat conditions. Mr. Don Warner, Chief of Air Force Fire Protection, and others viewed this technology as having the potential for use throughout DoD, particularly in desert and hot climate regions, while several other groups expressed an interest in the system for cooling, and chemical and biological decontamination.

The VRS humidification technology uses a chilled fine mist, with droplet sizes ranging from 10 to 40 microns, discharged from a 0.006 to 0.008 inch nozzle capable of flow rates of 5 to 15 pounds per hour. This combination of chilled water and pressurized air, dispersed at a controlled ratio through six unique nozzles, creates an atomized water vapor mist that decreases the air temperature in the surrounding area.

The ambient air temperature is lowered by the evaporating water droplets. Preliminary research has shown that a person surrounded by the cool mist experiences a lowering of body temperature and a refreshing interlude from the intense heat conditions around them.

As requested by Air Force Fire Protection, the AFRL Fire Research Group at Tyndall Air Force Base, Florida has recently integrated the VRS into a standard P-27 firefighting vehicle and performed preliminary evaluations at Avon Park,
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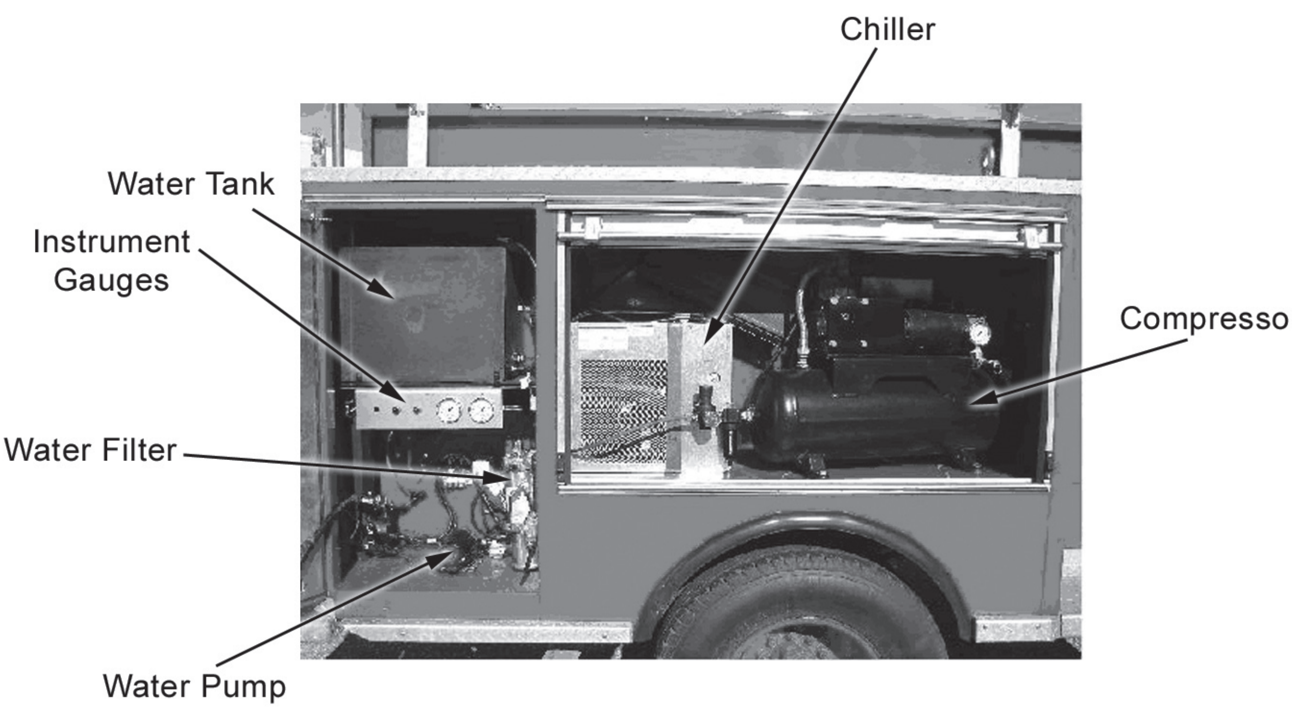

A firetruck with the Vapor Relief™ System installed.

Low Plasticity Burnishing Tested on 300M Aircraft Landing Gear Steel

AFRL engineers, working with industry, have made significant progress in the study and application of low plasticity burnishing (LPB) for the mitigation of stress corrosion cracking (SCC) and fatigue damage in high strength steels.

LPB, a process originated and patented by Lambda Technologies, has been previously demonstrated as an approach to substantially increase the foreign object damage (FOD) tolerance of turbine engine components.

In the most recent investigation, researchers at AFRL's Materials and Manufacturing Directorate (AFRL/ML) investigated the use of LPB on 300M steel, widely used for aircraft landing gear. They compared the results to those obtained using conventional shot peening (SP), the current state of the art. The tests indicated that LPB imparts persistent compressive residual stresses in 300M steel surfaces and that LPB-treated specimens more effectively withstand fatigue, FOD-related damage, and SCC.

4340 modified steel, also known as 300M, is used extensively for aircraft landing gear because of its high strength and other properties. Unfortunately, like other high-strength steels, 300M is vulnerable to corrosion fatigue and SCC, which, if left unresolved, can lead to catastrophic consequences in the landing gear. Plating and shot peening, used in conventional gear designs, are only partly effective. ML's Systems Support Division studied the effect of LPB treatment on several 300M steel specimens to determine whether the durability of the steel could be improved under adverse conditions. They used LPB to mechanically suppress stress sensitive corrosion failure mechanisms in a 3.5 percent salt solution, studied simulated FOD damage conditions, then compared their findings with SP and low stress ground (LSG) conditions.

LPB produced residual compression to a depth of 1.27 millimeters (mm) or 0.050 inches, and SP only 0.127 mm (0.005 inches), an order of magnitude less. LPB treatment dramatically improved the fatigue performance and resistance to SCC with and without simulated FOD. The fatigue life of LSG and SP surfaces was significantly lower with respect to the LPB baseline. The fatigue behavior was worse with FOD, simulated with a 0.5 mm (0.020 inches)-deep electrical discharge machining (EDM) notch, both in air and exposed to salt. (EDM is a metal removal machining method that uses an electrode under carefully controlled conditions to achieve a desired shape.) The researchers terminated the SCC testing of LPB-treated landing gear sections at 150 ksi (thousands of pounds per square inch) to 180 ksi static loads after 1500 hours without failure, noting that failure had occurred in as little as 13 hours without treatment.

Mechanistically, the effect of FOD resulted in early crack initiation and growth, resulting in a decrease in fatigue performance. Despite the existence of similar corrosion conditions, the deep compressive surface residual stresses from LPB treatment mitigated the individual and synergistic effects of corrosion and FOD. The deep compressive layer produced by LPB reduced surface stress, even under high tensile applied loads, suppressing the SCC failure mechanism. The research also demonstrated that LPB provides a deep layer of compressive residual stress that is stable throughout the range of stresses and thermal excursions typically encountered during landing gear manufacture and service. This allows a substantial increase in the fatigue performance of component features, without altering the alloy or design.

The LPB process was originally developed by Lambda Technologies in Cincinnati, Ohio. The basic LPB tool is comprised of a ball supported in a spherical hydrostatic bearing (Figure 1). The ball does not contact the bearing seat, even under load, and is loaded normal to the surface of a component with a hydraulic cylinder in the body of the tool. The ball rolls across the surface of the component in a pattern defined in the CNC code, as in the case of any machining operation. The pressure from the ball causes plastic deformation in the material underneath the ball. The deformed region is constrained by surrounding, undeformed material leaving the treated region in a state of compressive residual stress. No material is removed in the process, and the surface is displaced inward by only a few ten-thousandths of an inch. The tool path and normal pressure applied are designed to create a carefully engineered distribution of compressive residual stress, and the distribution is designed to counter applied stresses and optimize fatigue performance.

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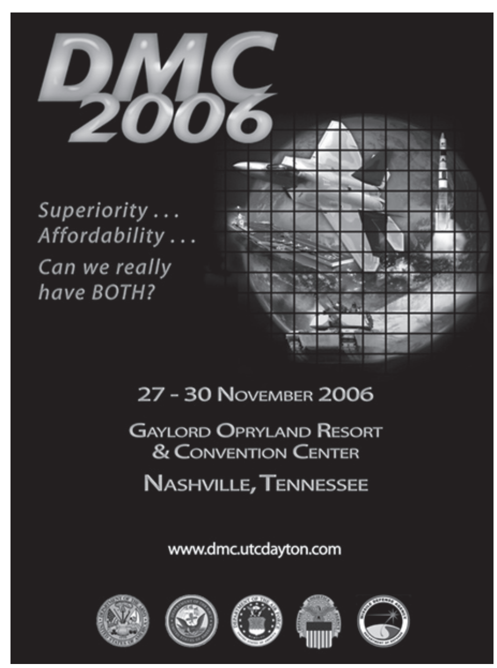
Florida, to determine the initial benefits this type of cooling system may provide firefighters in the field. A series of twenty-six evaluations were performed using eighteen firefighters to observe the effectiveness of this type of system to prevent heat exhaustion.

These evaluations were designed to determine what actually occurs when the atomized mist surrounds the body and the length of time it takes to render the body cooler and/or return to a fully functional level. During the tests, each firefighter was equipped with a radio frequency telemetry sensor that recorded heart rate, activity level and skin temperature. The firefighters performed physical labor for approximately twelve minutes, followed by a five-minute exposure to the cooling system while cooling down. Baseline data was obtained by performing a second set of tests in which firefighters were not exposed to the cooling system during the cool down period. This data indicated that a beneficial effect was achieved with the system.

The overall performance of the VRS in firefighter applications is currently under study; however, preliminary findings show that this innovative concept may have future potential to prevent firefighters from suffering the effects of heat stress brought on by the severe conditions in which they fight fires. When evaluations are completed, the cooling vapor technology may be considered for installation on future USAF fire vehicles.

For more information, contact the Materials and Manufacturing Directorate's Technical Information and Support Center at techinfo@afrl.af.mil or (937) 255-6469. Refer to item 05-330.



Scientist Leads Development of Polymer Made with DNA from Biowaste

AFRL is making significant contributions to bio-engineering through the investigation of a new class of polymer, or "biopolymer," based on DNA derived from biowaste materials.

Dr. James G. Grote, of the Laboratory's Materials and Manufacturing Directorate, assembled and led an international team to investigate this new biopolymer and its potential applications. His team demonstrated that the new material possesses unique optical and electromagnetic properties that no other known polymer has, including tunable conductivity and ultra low optical and microwave loss, making it optimal for high-speed applications.

Electro-optic and electronic devices fabricated from the new biopolymer have demonstrated enhanced performance compared to the state-of-the-art devices fabricated from current, organic-based materials. This new class of polymer has the potential to compete with, or even replace, many fossil fuel-based plastics for applications ranging from eyeglasses to food containers to higher technology applications, such as light-emitting diodes and transistors. Continuing research and development efforts could have profound impact on the Air Force and the Department of Defense, as well as commercial industry.

Dr. Grote has been actively involved in the development and application of nonlinear optic (NLO) polymer electro-optic (EO) materials and devices, since joining the ML in 1998. ML began preliminary in-house research in collaboration with the University of Southern California, University of Washington, and the Chitose Institute of Science and Technology in Japan to develop procedures for processing the DNA-based biopolymer into an optical waveguide quality material. The Air Force Office of Scientific Research (AFOSR) and the Asian Office and European Office of Aerospace Research and Development (AOARD and EOARD) supported this effort, which effectively demonstrated the new material's potential to enhance the performance of existing photonic and electronic devices, and led to the creation of AFRL's biopolymer photonics research effort.

As the research effort was showing additional promise, Dr. Grote recognized that other partners were necessary to help realize all of the advancements possible from this new technology. International collaborators, including a number of major universities, a second ML division, other AFRL directorates, government research institutions, and industry became actively involved.

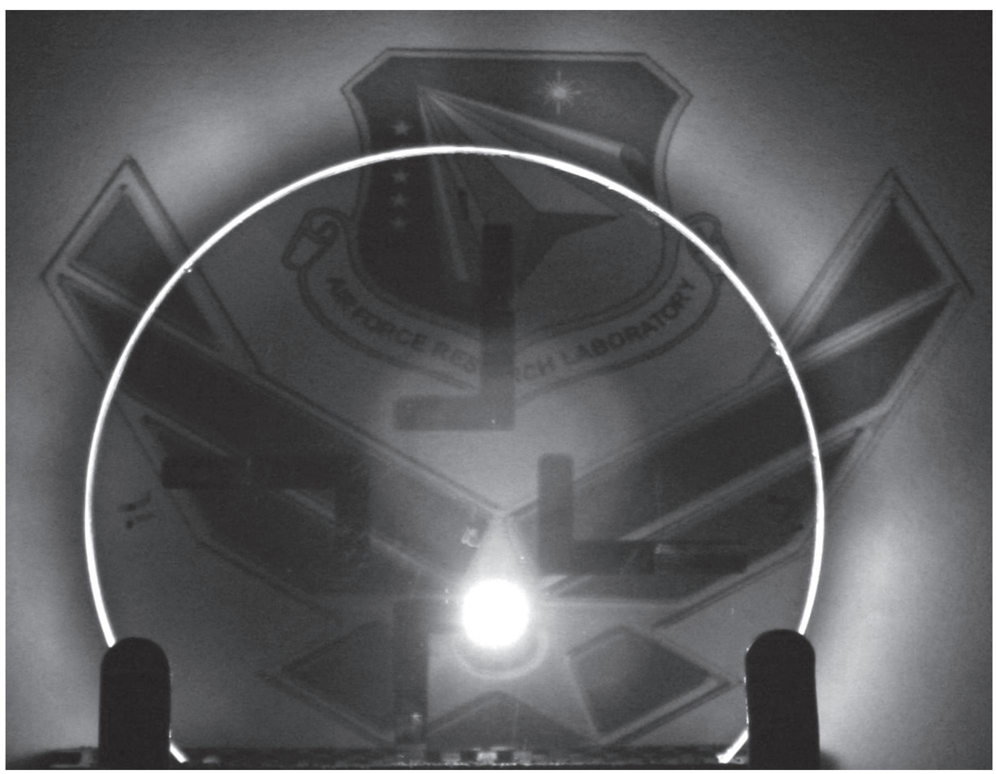
Dr. Grote's biopolymer has not only been successfully transferred to industry; it has also been transitioned directly to Air Force and Department of Defense development programs. The technology is being used or will be used for optical interconnects, light emitting diodes, lasers, electronics, and bio-molecular electronics and photonics. Dr. Grote's team is also transitioning the new biopolymer material within AFRL for radio frequency (RF) polymer-based EO modulator work and has transferred the new material to Lockheed Martin and IBM for optical interconnect applications.

In 2005, Dr. Grote organized the first international workshop on DNA-biopolymer photonics, which brought in government, industry, and university leaders in their respective areas of photonics and DNA from all over the world. Dr. Grote also successfully initiated new collaborative DNA-biopolymer research programs in Europe and the Pacific Rim. Additionally, he is investigating new domestic sources for purified DNA with Cargill and Ohio State University to enhance U.S. industries.

Under the engineering leadership and vision of Dr. Grote, biopolymers may be tomorrow's "silicon" of polymers with potential impact on a wide spectrum of photonic and electronic applications, while at the same time being inexpensive and easy to process. These important advances can be directly linked to Dr. Grote's guidance of the research, to his technical and contractual management of the international collaborative team, and to his focus on scientific quality, vitality, and relevance.

Dr. Grote received his doctorate degree in electrical engineering from the University of Dayton. He is a 2002 recipient of the prestigious AFRL/ML Charles J. Cleary Award for Scientific Achievement. He is also the 2006 winner of the Dr. Fritz J. Russ Bio-Engineering Award, presented annually by the Dayton chapter of the Institute of Electrical and Electronics Engineers (IEEE).

For more information, contact the Materials and Manufacturing Directorate's Technical Information and Support Center at techinfo@afrl.af.mil or (937) 255-6469. Refer to item 05-460.



A Bio-organic Light-Emitting Diode (BioLED).

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The process design for test samples and actual hardware is critical for optimized performance. In addition to ensuring that the design has sufficient compression to meet performance requirements, the design process must take into account the potential for redistribution of the induced compression through thermal and mechanical means, as well as the location and magnitude of compensatory tensile stresses. Efforts are underway to expand the study to hardware containing more complex designs.

Low plasticity burnishing offers greater depth and stability, and higher performance than conventional shot peening. In addition, LPB can be performed during manufacturing using standard computer numeric control (CNC) machine tools, eliminating the need for shipping components to other facilities for surface treatments. Continuing research efforts could result in more durable steel components for military and commercial aircraft landing gear.

For more information, contact the Materials and Manufacturing Directorate's Technical Information and Support Center at techinfo@afrl.af.mil or (937) 255-6469. Refer to item 05-047.

The USAF Materials Technology Highlights is published quarterly to provide information on materials research and development activities by Air Force Research Laboratory's Materials & Manufacturing Directorate. For more information on subjects covered in "Highlights" or to be added to the "Highlights" mailing list, contact the Materials & Manufacturing Directorate Technology Information and Support Center at (937) 255-6469 or e-mail at techinfo@afrl.af.mil. Approved for Public Release (AFRL/WS#06-1619).

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